## Remarks

The Office Action mailed May 7, 2003, has been received and reviewed. Claims 1, 15-17, and 26 having been amended, and claims 27-29 having been added, the pending claims are claims 1-29. Reconsideration and withdrawal of the rejections are respectfully requested. Support for the amendment to claims 1, 16, 17, and 26 can be found in the example at page 15. Support for the amendment to claim 15 and for new claims 27-29 can be found in the specification at page 9, lines 13-15.

### The 35 U.S.C. §102(e) Rejection

The Examiner rejected claim 15 under 35 U.S.C. §102(e) as being anticipated by Beitel et al. (U.S. 2002/0017063 A1). This rejection is respectfully traversed.

Claim 15 has been amended to recite that the polishing surface comprises a fixed abrasive article or a polishing pad, and when the polishing surface comprises a polishing pad the planarization composition comprises a plurality of abrasive particles having a hardness of no greater than 9 Mohs.

Beitel et al. do not teach or suggest the use of a fixed abrasive article as recited in Applicants' claim 15. Furthermore, there is no motivation to modify Beitel et al. to use a fixed abrasive article. Methods that use a polishing pad and an abrasive slurry, which is what is disclosed in Beitel et al., are not necessarily readily converted to the use of a fixed abrasive article with the expectation of similar results.

Also, Beitel et al. do not teach or suggest a planarization method that uses a polishing pad and a planarization composition that includes abrasive particles having a hardness of no greater than 9 Mohs (as recited in Applicants' claim 15). Beitel et al. teach the use of diamond. Diamond has a hardness of greater than 9 (see Exhibit A, which indicates that silicon carbide has a hardness of 9+ Mohs, and states that this hardness is "just under diamond"). Furthermore, there is no motivation to modify Beitel et al. to replace the diamond with abrasive particles having a hardness of no greater than 9 Mohs. Even if there were such motivation, there

is no expectation of success. Not all abrasive particles necessarily work the same with respect to removal rates and/or incorporation of defects, for example. Withdrawal of this rejection is respectfully requested.

## The 35 U.S.C. §103(a) Rejections

The Examiner rejected claims 1-6, 10-14, 16-19, and 22-26 under 35 U.S.C. §103(a) as being unpatentable over Beitel et al. in view of Weast et al. ("CRC Handbook of Chemistry and Physics"). This rejection is respectfully traversed.

The Examiner rejected claims 1, 7-9, 17, and 20-21 under 35 U.S.C. §103(a) as being unpatentable over Russell et al. (U.S. Patent 6,395,194) in view of Weast et al. This rejection is respectfully traversed.

Independent claims 1, 16, 17, and 26 have been amended to recite that the oxidizing agent is added to the planarization composition in the form of a gas. In contrast, Russel et al. generate a gas (e.g., $Br_2$) *in situ*. See, for example, column 5, lines 64-67. Beitel et al. discloses the use of oxygen and ozone, but is silent as to how they are added. See, for example, column 2, paragraph 20. Thus, neither Beitel et al. or Russel et al. teaches or suggests the addition of the oxidizing agent as a gas. Such a method of preparing the planarization composition provides advantages over *in situ* generation of the gas, for example. One such advantage is the better control of the amount of oxidizing gas incorporated into the planarization composition.

Weast et al. do not teach that which is missing from Beitel et al. or Russel et al. And, there is no motivation to modify any of these three documents to come up with Applicants' invention. Withdrawal of these rejections are respectfully requested.

## Summary

It is respectfully submitted that the pending claims 1-29 are in condition for allowance and notification to that effect is respectfully requested. The Examiner is invited to contact Applicants' Representatives, at the below-listed telephone number, if it is believed that prosecution of this application may be assisted thereby.

Respectfully submitted for
Uhlenbrock et al.

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Sept. 8, 2003
Date

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AMM/jra

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CERTIFICATE UNDER 37 CFR §1.10:
"Express Mail" mailing label number: EV 073 735 949 US Date of Deposit: 8 September 2003
I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR §1.10 on the date indicated above and is addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.
By: Jill R Aguilar
Name: JILL R AGUILAR

**Exhibit A**

# Tech Bulletin

## Abrasive Selection Guide

The effect of an abrasive material is caused by its three characteristics: shape, hardness, and particle size. The micro-abrasive media needed for a particular task is determined by the action or "effect" it produces.

**Particle Shape** - Individual particles that have points and edges such as blocky or needle shaped particles will cut and strip away surface material on impact. Spherical shaped particles do not have any cutting edges and are used to pound or "peen" a surface.

**Hardness** - The hardness of a selected media determines the ability of the particle to remove layers of the work piece material. Harder particles will be more aggressive. The hardness of abrasive media is measured using the Moh's scale.

**Particle Size** - A larger particle generates a greater impact force as it strikes the work piece. This has two effects. The first is that it removes material faster. The second is that it tends to produce a heavier texture or rougher surface on the base material.

### Aluminum Oxide

| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 10 | 0.0004 | Blocky & Sharp | 9 |
| 17.5 | 0.0007 | | |
| 25 | 0.001 | | |
| 50 | 0.002 | | |
| 100 | 0.004 | | |
| 150 | 0.006 | | |

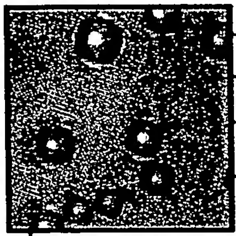
Description: Aluminum oxide is the most commonly used cutting abrasive. The shape and hardness of the particle make it an excellent choice when working with metals or hard brittle parts. Common uses for aluminum oxide include cutting, deburring and the preparation of surfaces. It is available in a wide range of sizes from 10 to 150 microns.

# Micro-Abrasive Media Selection Guide

## Crushed Glass

| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 50 | 0.002 | Blocky & Sharp | Between 5 and 6 |

Description: This media is manufactured by crushing glass beads. The result is a mild abrasive media. It has the hardness of glass bead, 5 to 6 on the Moh's scale, with lots of shard-like edges. Crushed glass is used where only a light degree of abrading is desired.



## Glass Bead

| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 50 | 0.002 | Spherical | 6 |

Description: Glass bead is commonly used where the preservation of tight tolerances is critical combined with the need to relieve machined stresses. It is also used to perform light deburring or to apply a satin-like finish on a part. The spherical shape of the glass bead keeps it from cutting into the surface of a part, so it is commonly used to relieve stresses by "pounding" the part's surface.

## Plastic Media

| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 200 | 0.008 | Blocky | Between 2 and 4 |

Description: This media is obtained by grinding and carefully sizing recycled plastic. It has a size similar to that of walnut shell. Its size makes it an effective tool to deburr machined plastic parts without causing dimensional changes. Plastic media can also be used to remove conformal coatings.

## Silicon Carbide

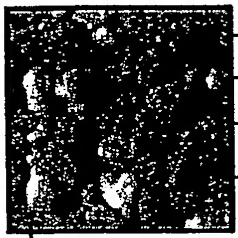
| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 20 | 0.0008 | Blocky & Sharp | 9 + |
| 50 | 0.002 | | |

Description: This is the most aggressive media used for micro-abrasive blasting. It has a hardness over 9 on the Moh's scale, just under diamond. This media is typically used only where very fast material removal is a requirement. Silicon carbide is an excellent abrasive for deburring stainless steel and titanium parts. *

**Sodium Bicarbonate**

| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 50 | 0.002 | Monoclinic | Between 3 and 4 |

Description: Sodium bicarbonate is one of the softest abrasives available, but the particles' needle-like or "monoclinic" shape makes it an excellent choice for abrading more pliable materials. The particles cut through soft surfaces where a blockier particle would tend to bounce off. It is commonly used to selectively remove the coating on a circuit board without damaging the individual components.



**Walnut Shell**

| Particle Size | | Particle Shape | Hardness (Moh's) |
|---|---|---|---|
| Micron | Inch | | |
| 250 | 0.010 | Blocky | Between 3 and 4 |

Description: Walnut shell is manufactured by grinding nut shells. It has a much larger size than sodium bicarbonate, approximately 200 to 250 microns. Walnut shell will quickly remove polymer coatings from circuit board surfaces and can also be used to deflash plastic parts.

## Selection of the Correct Abrasive Media

The selection of a particular media is always dictated by the type of work to be performed and what material will be treated. As this chart outlines, abrasive media ranges from soft sodium bicarbonate to hard silicon carbide.

Media used in micro-abrasive blasting is very different from anything used in a larger "grit" blaster. The micro-abrasive blasting media must be free of impurities and dry with a typical moisture content of less than 1%.

The Technical Support team at Comco has been specially trained to supply our customers with the correct solutions to a multitude of applications. They can confidently recommend the best abrasive media for specific uses across a wide variety of industries.

*Additional information on Micro-Abrasive Media may be found in other Comco Technical Bulletins including "Micro-Abrasive Blasting Recycling Issues" and "Moisture Issues: The Importance of Clean, Dry Air."*

# CRC Handbook of Chemistry and Physics

A Ready-Reference Book of Chemical and Physical Data

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# CONVERSION FORMULAE FOR SOLUTIONS HAVING CONCENTRATIONS EXPRESSED IN VARIOUS WAYS

A = Weight per cent of solute
B = Molecular weight of solvent
E = Molecular weight of solute
F = Grams of solute per liter of solution
G = Molality
M = Molarity
N = Mole fraction
R = Density of solution grams per cc

| Concentration of solute— SOUGHT | Concentration of solute—GIVEN | | | | |
|---|---|---|---|---|---|
| | A | N | G | M | F |
| A | — | $\frac{100N \times E}{N \times E + (1 - N)B}$ | $\frac{100G \times E}{1000 + G \times E}$ | $\frac{M \times E}{10R}$ | $\frac{F}{10R}$ |
| N | $\frac{\frac{A}{E}}{\frac{A}{E} + \frac{100 - A}{B}}$ | — | $\frac{B \times G}{B \times G + 1000}$ | $\frac{B \times M}{M(B - E) + 1000R}$ | $\frac{B \times F}{F(B - E) + 1000R \times E}$ |
| G | $\frac{1000A}{E(100 - A)}$ | $\frac{1000N}{B - N \times B}$ | — | $\frac{1000M}{1000R - (M \times E)}$ | $\frac{1000F}{E(1000R - F)}$ |
| M | $\frac{10R \times A}{E}$ | $\frac{1000R \times N}{N \times E + (1 - N)B}$ | $\frac{1000R \times G}{1000 + E \times G}$ | — | $\frac{F}{E}$ |
| F | 10AR | $\frac{1000R \times N \times E}{N \times E + (1 - N)B}$ | $\frac{1000R \times G \times E}{1000 + G \times E}$ | M × E | — |

# ELECTROCHEMICAL SERIES

### Petr Vanýsek

There are three tables for this Electrochemical Series. Each table lists standard reduction potentials, E° values, at 298.15 K (25°C), and at a pressure of 101.325 kPa (1 atm.). Table 1 is an alphabetical listing of the elements according to the symbols for the elements. Thus, data for Silver (Ag) precedes those for Aluminum (Al). Table 2 lists only those reduction reactions which have E° values positive to the potential of the Standard Hydrogen Electrode. In Table 2, the reactions are listed in the order of increasing positive potential and range from 0.000 V to +3.053 V. Table 3 lists only those reduction reactions which have E° values negative to the potential of the Standard Hydrogen Electrode. In Table 3, reactions are listed in the order of increasing negative potential and range from −0.017 to −4.10 V.

## Table 1
## ALPHABETICAL LISTING

| Reaction | E°, V |
|---|---|
| $Ag^+ + e \rightleftharpoons Ag$ | 0.7996 |
| $Ag^{2+} + e \rightleftharpoons Ag^+$ | 1.980 |
| $Ag(ac) + e \rightleftharpoons Ag + (ac)^-$ | 0.643 |
| $AgBr + e \rightleftharpoons Ag + Br^-$ | 0.07133 |
| $AgBrO_3 + e \rightleftharpoons Ag + BrO_3^-$ | 0.546 |
| $Ag_2C_2O_4 + 2\,e \rightleftharpoons 2Ag + C_2O_{44}^{2-}$ | 0.4647 |
| $AgCl + e \rightleftharpoons Ag + Cl^-$ | 0.22233 |
| $AgCN + e \rightleftharpoons Ag + CN^-$ | −0.017 |
| $Ag_2CO_3 + 2\,e \rightleftharpoons 2\,Ag + CO_3^{2-}$ | 0.47 |
| $Ag_2CrO_4 + 2\,e \rightleftharpoons 2\,Ag + CrO_4^{2-}$ | 0.4470 |
| $AgF + e \rightleftharpoons Ag + F^-$ | 0.779 |
| $Ag_4[Fe(CN)_6] + 4\,e \rightleftharpoons 4\,Ag + [Fe(CN)_6]^{4-}$ | 0.1478 |
| $AgI + e \rightleftharpoons Ag + I^-$ | −0.15224 |
| $AgIO_3 + e \rightleftharpoons Ag + IO_3^-$ | 0.354 |
| $Ag_2MoO_4 + 2\,e \rightleftharpoons 2\,Ag + MoO_4^{2-}$ | 0.4573 |
| $AgNO_2 + e \rightleftharpoons Ag + NO_2^-$ | 0.564 |
| $Ag_2O + H_2O + 2\,e \rightleftharpoons 2\,Ag + 2\,OH^-$ | 0.342 |
| $Ag_2O_3 + H_2O + 2\,e \rightleftharpoons 2\,AgO + 2\,OH^-$ | 0.739 |
| $AgO + H_2O + 2\,e \rightleftharpoons Ag_2O + 2\,OH^-$ | 0.607 |
| $AgOCN + e \rightleftharpoons Ag + OCN^-$ | 0.41 |
| $Ag_2S + 2\,e \rightleftharpoons 2\,Ag + S^{2-}$ | −0.691 |
| $Ag_2S + 2\,H^+ + 2\,e \rightleftharpoons 2\,Ag + H_2S$ | −0.0366 |
| $AgSCN + e \rightleftharpoons Ag + SCN^-$ | 0.08951 |
| $Ag_2SeO_3 + 2\,e \rightleftharpoons 2\,Ag + SeO_4^{2-}$ | 0.3629 |
| $Ag_2SO_4 + 2\,e \rightleftharpoons 2\,Ag + SO_4^{2-}$ | 0.654 |
| $Ag_2WO_4 + 2\,e \rightleftharpoons 2\,Ag + WO_4^{2-}$ | 0.4660 |
| $Al^{3+} + 3\,e \rightleftharpoons Al$ | −1.662 |
| $H_2AlO_3^- + H_2O + 3\,e \rightleftharpoons Al + 4\,OH^-$ | −2.33 |
| $AlF_6^{3-} + 3\,e \rightleftharpoons Al + 6\,F^-$ | −2.069 |
| $As + 3H^+ + 3\,e \rightleftharpoons AsH_3$ | −0.608 |
| $As_2O_3 + 6\,H^+ + 6\,e \rightleftharpoons 2\,As + 3\,H_2O$ | 0.234 |
| $HAsO_2 + 3\,H^+ + 3\,e \rightleftharpoons As + 2\,H_2O$ | 0.248 |
| $AsO_2^- + 2\,H_2O + 3\,e \rightleftharpoons As + 4\,OH^-$ | −0.68 |
| $H_3AsO_4 + 2\,H^+ + 2\,e^- \rightleftharpoons HAsO_2 + 2\,H_2O$ | 0.560 |
| $AsO_4^{3-} + 2\,H_2O + 2\,e \rightleftharpoons AsO_2^- + 4\,OH^-$ | −0.71 |
| $Au^+ + e \rightleftharpoons Au$ | 1.692 |
| $Au^{3+} + 2\,e \rightleftharpoons Au^+$ | 1.401 |
| $Au^{3+} + 3\,e \rightleftharpoons Au$ | 1.498 |
| $AuBr_2^- + e \rightleftharpoons Au + 2\,Br^-$ | 0.959 |
| $AuBr_4^- + 3\,e \rightleftharpoons Au + 4\,Br^-$ | 0.854 |
| $AuCl_4^- + 3\,e \rightleftharpoons Au + 4\,Cl^-$ | 1.002 |
| $Au(OH)_3 + 3\,H^+ + 3\,e \rightleftharpoons Au + 3\,H_2O$ | 1.45 |
| $H_2BO_3^- + 5\,H_2O + 8\,e \rightleftharpoons BH_4^- + 8\,OH^-$ | −1.24 |
| $H_2BO_3^- + H_2O + 3\,e \rightleftharpoons B + 4\,OH^-$ | −1.79 |
| $H_3BO_3 + 3\,H^+ + 3\,e \rightleftharpoons B + 3\,H_2O$ | −0.8698 |
| $Ba^{2+} + 2\,e \rightleftharpoons Ba$ | −2.912 |
| $Ba^{2+} + 2\,e \rightleftharpoons Ba(Hg)$ | −1.570 |
| $Ba(OH)_2 + 2\,e \rightleftharpoons Ba + 2\,OH^-$ | −2.99 |
| $Be^{2+} + 2\,e \rightleftharpoons Be$ | −1.847 |
| $Be_2O_3^{2-} + 3\,H_2O + 4\,e \rightleftharpoons 2\,Be + 6\,OH^-$ | −2.63 |

## Table 1 (continued)
## ALPHABETICAL LISTING

| Reaction | E°, V |
|---|---|
| p-benzoquinone + 2 $H^+$ + 2 e ⇌ hydroquinone | 0.6992 |
| $BiCl_4^-$ + 3 e ⇌ Bi + 4 $Cl^-$ | 0.16 |
| $Bi_2O_3$ + 3 $H_2O$ + 6 e ⇌ 2 Bi + 6 $OH^-$ | −0.46 |
| $Bi_2O_4$ + 4 $H^+$ + 2 e ⇌ 2 $BiO^+$ + 2 $H_2O$ | 1.593 |
| $BiO^+$ + 2 $H^+$ + 3 e ⇌ Bi + $H_2O$ | 0.320 |
| BiOCl + 2 $H^+$ + 3 e ⇌ Bi + $Cl^-$ + $H_2O$ | 0.1583 |
| $Br_2$(aq) + 2 e ⇌ 2 $Br^-$ | 1.0873 |
| $Br_2$(l) + 2 e ⇌ 2 $Br^-$ | 1.066 |
| HBrO + $H^+$ + 2 e ⇌ $Br^-$ + $H_2O$ | 1.331 |
| HBrO + $H^+$ + e ⇌ 1/2$Br_2$(aq) + $H_2O$ | 1.574 |
| HBrO + $H^+$ + e ⇌ 1/2$Br_2$(ℓ) + $H_2O$ | 1.596 |
| $BrO^-$ + $H_2O$ + 2 e ⇌ $Br^-$ + 2 $OH^-$ | 0.761 |
| $BrO_3^-$ + 6 $H^+$ + 5 e ⇌ 1/2$Br_2$ + 3 $H_2O$ | 1.482 |
| $BrO_3^-$ + 6 $H^+$ + 6 e ⇌ $Br^-$ + 3 $H_2O$ | 1.423 |
| $BrO_3^-$ + 3 $H_2O$ + 6 e ⇌ $Br^-$ + 6 $OH^-$ | 0.61 |
| $Ca^+$ + e ⇌ Ca | −3.80 |
| $Ca^{2+}$ + 2 e ⇌ Ca | −2.868 |
| Calomel electrode, 1 molal KCl | 0.2800 |
| Calomel electrode, 1 mol/ℓ KCl (NCE) | 0.2801 |
| Calomel electrode, 0.1 mol/ℓ KCl | 0.3337 |
| Calomel electrode, saturated KCl (SCE) | 0.2412 |
| Calomel electrode, saturated NaCl (SSCE) | 0.2360 |
| $Ca(OH)_2$ + 2 e ⇌ Ca + 2 $OH^-$ | −3.02 |
| $Cd^{2+}$ + 2 e ⇌ Cd | −0.4030 |
| $Cd^{2+}$ + 2 e ⇌ Cd(Hg) | −0.3521 |
| $Cd(OH)_2$ + 2 e ⇌ Cd(Hg) + 2 $OH^-$ | −0.809 |
| $CdSO_4$ + 2 e ⇌ Cd + $SO_4^{2-}$ | −0.246 |
| $Ce^{3+}$ + 3 e ⇌ Ce | −2.483 |
| $Ce^{3+}$ + 3 e ⇌ Ce(Hg) | −1.4373 |
| $Ce^{4+}$ + e ⇌ $Ce^{3+}$ | 1.61 |
| $CeOH^{3+}$ + $H^+$ + e ⇌ $Ce^{3+}$ + $H_2O$ | 1.715 |
| $Cl_2$(g) + 2 e ⇌ $Cl^-$ | 1.35827 |
| HClO + $H^+$ + e ⇌ 1/2$Cl_2$ + $H_2O$ | 1.611 |
| HClO + $H^+$ 2 e ⇌ $Cl^-$ + $H_2O$ | 1.482 |
| $ClO^-$ + $H_2O$ + 2 e ⇌ $Cl^-$ + 2 $OH^-$ | 0.81 |
| $ClO_2$ + $H^+$ + e ⇌ $HClO_2$ | 1.277 |
| $HClO_2$ + 2 $H^+$ + 2 e ⇌ HClO + $H_2O$ | 1.645 |
| $HClO_2$ + 3 $H^+$ + 3 e ⇌ 1/2$Cl_2$ + 2 $H_2O$ | 1.628 |
| $HClO_2$ + 3 $H^+$ + 4 e ⇌ $Cl^-$ + 2 $H_2O$ | 1.570 |
| $ClO_2^-$ + $H_2O$ + 2 e ⇌ $ClO^-$ + 2 $OH^-$ | 0.66 |
| $ClO_2^-$ + 2 $H_2O$ + 4 e ⇌ $Cl^-$ + 4 $OH^-$ | 0.76 |
| $ClO_2$(aq) + e ⇌ $ClO_2^-$ | 0.954 |
| $ClO_3^-$ + 2 $H^+$ + e ⇌ $ClO_2$ + $H_2O$ | 1.152 |
| $ClO_3^-$ + 3 $H^+$ + 2 e ⇌ $HClO_2$ + $H_2O$ | 1.214 |
| $ClO_3^-$ + 6 $H^+$ + 5 e ⇌ 1/2$Cl_2$ + 3 $H_2O$ | 1.47 |
| $ClO_3^-$ + 6 $H^+$ + 6 e ⇌ $Cl^-$ + 3 $H_2O$ | 1.451 |
| $ClO_3^-$ + $H_2O$ + 2 e ⇌ $ClO_2^-$ + 2 $OH^-$ | 0.33 |
| $ClO_3^-$ + 3 $H_2O$ + 6 e ⇌ $Cl^-$ + 6 $OH^-$ | 0.62 |
| $ClO_4^-$ + 2 $H^+$ + 2 e ⇌ $ClO_3^-$ + $H_2O$ | 1.189 |
| $ClO_4^-$ + 8 $H^+$ + 7 e ⇌ 1/2$Cl_2$ + 4 $H_2O$ | 1.39 |
| $ClO_4^-$ + 8 $H^+$ + 8 e ⇌ $Cl^-$ + 4 $H_2O$ | 1.389 |
| $ClO_4^-$ + $H_2O$ + 2 e ⇌ $ClO_3^-$ + 2 $OH^-$ | 0.36 |
| $(CN)_2$ + 2 $H^+$ + 2 e ⇌ 2 HCN | 0.373 |
| 2 HCNO + 2 $H^+$ + 2 e ⇌ $(CN)_2$ + 2 $H_2O$ | 0.330 |
| $(CNS)_2$ + 2 e ⇌ 2 $CNS^-$ | 0.77 |
| $Co^{2+}$ + 2 e ⇌ Co | −0.28 |

| Reaction | E°, V |
|---|---|
| $Co^{3+}$ + e ⇌ $Co^{2+}$ (2 mol/ℓ $H_2SO_4$) | 1.83 |
| $[Co(NH_3)_6]^{3+}$ + e ⇌ $[Co(NH_3)_6]^{2+}$ | 0.108 |
| $Co(OH)_2$ + 2 e ⇌ Co + 2 $OH^-$ | −0.73 |
| $Co(OH)_3$ + e ⇌ $Co(OH)_2$ + $OH^-$ | 0.17 |
| $CO_2$ + 2 $H^+$ + 2 e ⇌ HCOOH | −0.199 |
| $Cr^{2+}$ + 2 e ⇌ Cr | −0.913 |
| $Cr^{3+}$ + e ⇌ $Cr^{2+}$ | −0.407 |
| $Cr^{3+}$ + 3 e ⇌ Cr | −0.744 |
| $Cr_2O_7^{2-}$ + 14 $H^+$ + 6 e ⇌ 2 $Cr^{3+}$ + 7 $H_2O$ | 1.232 |
| $CrO_2^-$ + 2 $H_2O$ + 3 e ⇌ Cr + 4 $OH^-$ | −1.2 |
| $HCrO_4^{2-}$ + 7 $H^+$ + 3 e ⇌ $Cr^{3+}$ + 4 $H_2O$ | 1.350 |
| $CrO_4^-$ + 4 $H_2O$ + 3 e ⇌ $Cr(OH)_3$ + 5 $OH^-$ | −0.13 |
| $Cr(OH)_3$ + 3 e ⇌ Cr + 3 $OH^-$ | −1.48 |
| $Cs^+$ + e ⇌ Cs | −2.92 |
| $Cu^+$ + e ⇌ Cu | 0.521 |
| $Cu^{2+}$ + e ⇌ $Cu^+$ | 0.153 |
| $Cu^{2+}$ + 2 e ⇌ Cu | 0.3419 |
| $Cu^{2+}$ + 2 e ⇌ Cu(Hg) | 0.345 |
| $Cu^{2+}$ + 2 $CN^-$ + e ⇌ $[Cu(CN)_2]^-$ | 1.103 |
| $CuI_2^-$ + e ⇌ Cu + 2 $I^-$ | 0.00 |
| $Cu_2O$ + $H_2O$ + 2 e ⇌ 2 Cu + 2 $OH^-$ | −0.360 |
| $Cu(OH)_2$ + 2 e ⇌ Cu + 2 $OH^-$ | −0.222 |
| 2 $Cu(OH)_2$ + 2 e ⇌ $Cu_2O$ + 2 $OH^-$ + $H_2O$ | −0.080 |
| $D^+$ + e ⇌ 1/2$D_2$ | −0.0034 |
| 2 $D^+$ + 2 e ⇌ $D_2$ | −0.044 |
| $Eu^{2+}$ + 2 e ⇌ Eu | −3.395 |
| $Eu^{3+}$ + 3 e ⇌ Eu | −2.407 |
| $Eu^{3+}$ + e ⇌ $Eu^{2+}$ | −0.36 |
| $F_2$ + 2 $H^+$ + 2 e ⇌ 2 HF | 3.053 |
| $F_2$ + 2 e ⇌ 2 $F^-$ | 2.866 |
| $F_2O$ + 2 $H^+$ + 4 e ⇌ $H_2O$ + 2 $F^-$ | 2.15 |
| $Fe^{2+}$ + 2 e ⇌ Fe | −0.447 |
| $Fe^{3+}$ + 3 e ⇌ Fe | −0.03 |
| $Fe^{3+}$ + e ⇌ $Fe^{2+}$ | 0.77 |
| $[Fe(CN)_6]^{3-}$ + e ⇌ $[Fe(CN)_6]^{4-}$ | 0.35 |
| $FeO_4^{2-}$ + 8 $H^+$ + 3 e ⇌ $Fe^{3+}$ + 4 $H_2O$ | 2.20 |
| $Fe(OH)_3$ + e ⇌ $Fe(OH)_2$ + $OH^-$ | −0.5 |
| $[Fe(phenanthroline)_3]^{3+}$ + e ⇌ $[Fe(phen)_3]^{2+}$ | 1.1 |
| $[Fe(phen)_3]^{3+}$ + e ⇌ $[Fe(phen)_3]^{2+}$ (1 mol/ℓ $H_2SO_4$) | 1.0 |
| [Ferricinium]$^+$ + e ⇌ ferrocene | 0.40 |
| $Ga^{3+}$ + 3 e ⇌ Ga | −0.5 |
| $H_2GaO_3^-$ + $H_2O$ + 3 e ⇌ Ga + 4 $OH^-$ | −1.2 |
| $Ge^{2+}$ + 2 e ⇌ Ge | 0.2 |
| $Ge^{4+}$ + 4 e ⇌ Ge | 0.1 |
| $Ge^{4+}$ + 2 e ⇌ $Ge^{2+}$ | 0.0 |
| $GeO_2$ + 2 $H^+$ + 2 e ⇌ GeO + $H_2O$ | −0 |
| $H_2GeO_3$ + 4 $H^+$ + 4 e ⇌ Ge + 3 $H_2O$ | −0 |
| 2 $H^+$ + 2 e ⇌ $H_2$ | [illegible] |
| $H_2$ + 2 e ⇌ 2 $H^-$ | [illegible] |
| $HO_2$ + $H^+$ + e ⇌ $H_2O_2$ | [illegible] |
| 2 $H_2O$ + 2 e ⇌ $H_2$ + 2 $OH^-$ | [illegible] |
| $H_2O_2$ + 2 $H^+$ + 2 e ⇌ 2 $H_2O$ | [illegible] |
| $HfO^{2+}$ + 2 $H^+$ + 4 e ⇌ Hf + $H_2O$ | [illegible] |
| $HfO_2$ + 4 $H^+$ + 4 e ⇌ Hf + 2 $H_2O$ | [illegible] |
| $HfO(OH)_2$ + $H_2O$ + 4 e ⇌ Hf + 4 $OH^-$ | [illegible] |
| $Hg^{2+}$ + 2 e ⇌ Hg | [illegible] |
| 2 $Hg^{2+}$ + 2 e ⇌ $Hg_2^{2+}$ | [illegible] |
| $Hg_2^{2+}$ + 2 e ⇌ 2 Hg | [illegible] |

| |
|---|
| $Hg_2(ac)_2$ + 2 e |
| $Hg_2Br_2$ + 2 e |
| $Hg_2Cl_2$ + 2 e |
| $Hg_2HPO_4$ + 2 |
| $Hg_2I_2$ + 2 e |
| $Hg_2O$ + $H_2O$ |
| HgO + $H_2O$ |
| $Hg_2SO_4$ + 2 e |
| $I_2$ + 2 e ⇌ 2 |
| $I_3^-$ + 2 e |
| $H_3IO_6$ + 2 e |
| $H_5IO_6$ + $H^+$ |
| 2 HIO + 2 H |
| HIO + $H^+$ |
| $IO^-$ + $H_2O$ |
| 2 $IO_3$ + 12 |
| $IO_3^-$ + 6 $H^+$ |
| $IO_3^-$ + 2 $H_2O$ |
| $IO_3^-$ + 3 $H_2O$ |
| $In^+$ + e ⇌ In |
| $In^{2+}$ + e |
| $In^{3+}$ + e |
| $In^{3+}$ + 2 e |
| $In^{3+}$ + 3e |
| $Ir^{3+}$ + 3 e |
| $[IrCl_6]^{2-}$ + e |
| $[IrCl_6]^{3-}$ + 3 |
| $Ir_2O_3$ + 3 H |
| $K^+$ + e ⇌ K |
| $La^{3+}$ + 3 e |
| $La(OH)_3$ + |
| $Li^+$ + e |
| $Mg^+$ + e |
| $Mg^{2+}$ + 2 e |
| $Mg(OH)_2$ + |
| $Mn^{2+}$ + 2 e |
| $Mn^{3+}$ + 3 |
| $MnO_2$ + 4 H |
| $MnO_4$ + e |
| $MnO_4$ + 4 |
| $MnO_4^-$ + 8 |
| $MnO_4^-$ + 2 |
| $MnO_4^{2-}$ + |
| $Mn(OH)_2$ + |
| $Mn(OH)_3$ + |
| $Mo^{3+}$ + 3 |
| $N_2$ + 2 $H_2$ |
| 3 $N_2$ + 2 H |
| $N_3^-$ + 3 H |
| $N_2O$ + 2 H |
| $H_2N_2O_2$ + |
| $N_2O_4$ + 2 |
| $N_2O_4$ + 2 |
| $N_2O_4$ + 4 |
| 2 $NH_3OH$ |
| 2 NO + 2 |
| 2 NO + 2 |
| 2 NO + H |

## Table 1 (continued)
## ALPHABETICAL LISTING

| Reaction | E°, V |
|---|---|
| $PbSO_4 + 2 e \rightleftharpoons Pb(Hg) + SO_4^{2-}$ | −0.3505 |
| $Pd^{2+} + 2 e \rightleftharpoons Pd$ | 0.951 |
| $[PdCl_4]^{2-} + 2 e \rightleftharpoons Pd + 4 Cl^-$ | 0.591 |
| $[PdCl_6]^{2-} + 2 e \rightleftharpoons [PdCl_4]^{2-} + 2 Cl^-$ | 1.288 |
| $Pd(OH)_2 + 2 e \rightleftharpoons Pd + 2 OH^-$ | 0.07 |
| $Pt^{2+} + 2 e \rightleftharpoons Pt$ | 1.118 |
| $[PtCl_4]^{2-} + 2 e \rightleftharpoons Pt + 4 Cl^-$ | 0.755 |
| $[PtCl_6]^{2-} + 2 e \rightleftharpoons [PtCl_4]^{2-} + 2 Cl^-$ | 0.68 |
| $Pt(OH)_2 + 2 e \rightleftharpoons Pt + 2 OH^-$ | 0.14 |
| $Pu^{3+} + 3 e \rightleftharpoons Pu$ | −2.031 |
| $Pu^{4+} + e \rightleftharpoons Pu^{3+}$ | 1.006 |
| $Pu^{5+} + e \rightleftharpoons Pu^{4+}$ | 1.099 |
| $PuO_2(OH)_2 + 2 H^+ + 2 e \rightleftharpoons Pu(OH)_4$ | 1.325 |
| $PuO_2(OH)_2 + H^+ + e \rightleftharpoons PuO_2OH + H_2O$ | 1.062 |
| $Rb^+ + e \rightleftharpoons Rb$ | −2.98 |
| $Re^{3+} + 3 e \rightleftharpoons Re$ | 0.300 |
| $ReO_4^- + 4 H^+ + 3 e \rightleftharpoons ReO_2 + 2 H_2O$ | 0.510 |
| $ReO_2 + 4 H^+ + 4 e \rightleftharpoons Re + 2 H_2O$ | 0.2513 |
| $ReO_4^- + 2 H^+ + e \rightleftharpoons ReO_3 + H_2O$ | 0.768 |
| $ReO_4^- + 4 H_2O + 7 e \rightleftharpoons Re + 8 OH^-$ | −0.584 |
| $ReO_4^- + 8 H^+ + 7 e \rightleftharpoons Re + 4 H_2O$ | 0.368 |
| $Rh^+ + e \rightleftharpoons Rh$ | 0.600 |
| $Rh^{2+} + 2 e \rightleftharpoons Rh$ | 0.600 |
| $Rh^{3+} + 3 e \rightleftharpoons Rh$ | 0.758 |
| $[RhCl_6]^{3-} + 3 e \rightleftharpoons Rh + 6 Cl^-$ | 0.431 |
| $Ru^{2+} + 2 e \rightleftharpoons Ru$ | 0.455 |
| $Ru^{3+} + e \rightleftharpoons Ru^{2+}$ | 0.2487 |
| $RuO_2 + 4 H^+ + 2 e \rightleftharpoons Ru^{2+} + 2 H_2O$ | 1.120 |
| $RuO_4^- + e \rightleftharpoons RuO_4^{2-}$ | 0.59 |
| $RuO_4 + e \rightleftharpoons RuO_4^-$ | 1.00 |
| $S + 2 e \rightleftharpoons S^{2-}$ | −0.47627 |
| $S + 2H^+ + 2 e \rightleftharpoons H_2S(aq)$ | 0.142 |
| $S + H_2O + 2 e \rightleftharpoons HS^- + OH^-$ | −0.478 |
| $2 S + 2 e \rightleftharpoons S_2^{2-}$ | −0.42836 |
| $S_2O_6^{2-} + 4 H^+ + 2 e \rightleftharpoons 2 H_2SO_3$ | 0.564 |
| $S_2O_8^{2-} + 2 e \rightleftharpoons 2 SO_4^{2-}$ | 2.010 |
| $S_2O_8^{2-} + 2 H^+ + 2 e \rightleftharpoons 2 HSO_4^-$ | 2.123 |
| $S_4O_6^{2-} + 2 e \rightleftharpoons 2 S_2O_3^{2-}$ | 0.08 |
| $2 H_2SO_3 + H^+ + 2 e \rightleftharpoons HS_2O_4^- + 2 H_2O$ | −0.056 |
| $H_2SO_3 + 4 H^+ + 4 e \rightleftharpoons S + 3 H_2O$ | 0.449 |
| $2 SO_3^{2-} + 2 H_2O + 2 e \rightleftharpoons S_2O_4^{2-} + 4 OH^-$ | −1.12 |
| $2 SO_3^{2-} + 3 H_2O + 4 e \rightleftharpoons S_2O_3^{2-} + 6 OH^-$ | −0.571 |
| $SO_4^{2-} + 4 H^+ + 2 e \rightleftharpoons H_2SO_3 + H_2O$ | 0.172 |
| $2 SO_4^{2-} + 4 H^+ + 2 e \rightleftharpoons S_2O_6^{2-} + H_2O$ | −0.22 |
| $SO_4^{2-} + H_2O + 2 e \rightleftharpoons SO_3^{2-} + 2 OH^-$ | −0.93 |
| $Sb + 3 H^+ + 3 e \rightleftharpoons SbH_3$ | −0.510 |
| $Sb_2O_3 + 6 H^+ + 6 e \rightleftharpoons 2 Sb + 3 H_2O$ | 0.152 |
| $Sb_2O_5$ (senarmontite) $+ 4 H^+ + 4 e \rightleftharpoons Sb_2O_3 + 2 H_2O$ | 0.671 |
| $Sb_2O_5$ (valentinite) $+ 4 H^+ + 4 e \rightleftharpoons Sb_2O_3 + 2 H_2O$ | 0.649 |
| $Sb_2O_5 + 6 H^+ + 4 e \rightleftharpoons 2 SbO^+ + 3 H_2O$ | 0.581 |
| $SbO^+ + 2 H^+ + 3 e \rightleftharpoons Sb + 2 H_2O$ | 0.212 |
| $SbO_2^- + 2 H_2O + 3 e \rightleftharpoons Sb + 4 OH^-$ | −0.66 |
| $SbO_3^- + H_2O + 2 e \rightleftharpoons SbO_2^- + 2 OH^-$ | −0.59 |
| $Sc^{3+} + 3 e \rightleftharpoons Sc$ | −2.077 |
| $Se + 2 e \rightleftharpoons Se^{2-}$ | −0.924 |
| $Se + 2 H^+ + 2 e \rightleftharpoons H_2Se(aq)$ | −0.39 |
| $H_2SeO_3 + 4 H^+ + 4 e \rightleftharpoons Se + 3 H_2O$ | −0.74 |
| $SeO_3^{2-} + 3 H_2O + 4 e \rightleftharpoons Se + 6 OH^-$ | −0.366 |
| $SeO_4^{2-} + 4 H^+ + 2 e \rightleftharpoons H_2SeO_3 + H_2O$ | 1.151 |
| $SeO_4^{2-} + H_2O + 2 e \rightleftharpoons SeO_3^{2-} + 2 OH^-$ | 0.05 |
| $SiF_6^{2-} + 4 e \rightleftharpoons Si + 6 F^-$ | −1.24 |
| $SiO_2$ (quartz) $+ 4 H^+ + 4 e \rightleftharpoons Si + 2 H_2O$ | 0.857 |
| $SiO_3^{2-} + 3 H_2O + 4 e \rightleftharpoons Si + 6 OH^-$ | −1.697 |
| $Sn^{2+} + 2 e \rightleftharpoons Sn$ | −0.1375 |
| $Sn^{4+} + 2 e \rightleftharpoons Sn^{2+}$ | 0.151 |
| $HSnO_2^- + H_2O + 2 e \rightleftharpoons Sn + 3 OH^-$ | −0.909 |
| $Sn(OH)_6^{2-} + 2 e \rightleftharpoons HSnO_2^- + 3 OH^- + H_2O$ | −0.93 |
| $Sr^+ + e \rightleftharpoons Sr$ | −4.10 |
| $Sr^{2+} + 2 e \rightleftharpoons Sr$ | −2.89 |
| $Sr^{2+} + 2 e \rightleftharpoons Sr(Hg)$ | −1.793 |
| $Sr(OH)_2 + 2 e \rightleftharpoons Sr + 2 OH^-$ | −2.88 |
| $Ta_2O_5 + 10 H^+ + 10 e \rightleftharpoons 2 Ta + 5 H_2O$ | −0.750 |
| $Tc^{2+} + 2 e \rightleftharpoons Tc$ | 0.400 |
| $TcO_4^- + 4 H^+ + 3 e \rightleftharpoons TcO_2 + 2 H_2O$ | 0.782 |
| $Te + 2 e \rightleftharpoons Te^{2-}$ | −1.143 |
| $Te + 2 H^+ + 2 e \rightleftharpoons H_2Te$ | −0.793 |
| $Te^{4+} + 4 e \rightleftharpoons Te$ | 0.568 |
| $TeO_2 + 4 H^+ + 4 e \rightleftharpoons Te + 2 H_2O$ | 0.593 |
| $TeO_3^{2-} + 3 H_2O + 4 e \rightleftharpoons Te + 6 OH^-$ | −0.57 |
| $TeO_4^- + 8 H^+ + 7 e \rightleftharpoons Te + 4 H_2O$ | 0.472 |
| $H_6TeO_6 + 2 H^+ + 2 e \rightleftharpoons TeO_2 + 4 H_2O$ | 1.02 |
| $Th^{4+} + 4 e \rightleftharpoons Th$ | −1.899 |
| $ThO_2 + 4 H^+ + 4 e \rightleftharpoons Th + 2 H_2O$ | −1.789 |
| $Th(OH)_4 + 4 e \rightleftharpoons Th + 4 OH^-$ | −2.48 |
| $Ti^{2+} + 2 e \rightleftharpoons Ti$ | −1.630 |
| $Ti^{3+} + e \rightleftharpoons Ti^{2+}$ | −0.368 |
| $TiO_2 + 4 H^+ + 2 e \rightleftharpoons Ti^{2+} + 2 H_2O$ | −0.502 |
| $TiOH^{3+} + H^+ + e \rightleftharpoons Ti^{3+} + H_2O$ | −0.055 |
| $Tl^+ + e \rightleftharpoons Tl$ | −0.336 |
| $Tl^+ + e \rightleftharpoons Tl(Hg)$ | −0.3338 |
| $Tl^{3+} + 2 e \rightleftharpoons Tl^+$ | 1.252 |
| $TlBr + e \rightleftharpoons Tl + Br^-$ | −0.658 |
| $TlCl + e \rightleftharpoons Tl + Cl^-$ | −0.5568 |
| $TlI + e \rightleftharpoons Tl + I^-$ | −0.752 |
| $Tl_2O_3 + 3 H_2O + 4 e \rightleftharpoons 2 Tl^+ + 6 OH^-$ | 0.02 |
| $TlOH + e \rightleftharpoons Tl + OH^-$ | −0.34 |
| $Tl(OH)_3 + 2 e \rightleftharpoons TlOH + 2 OH^-$ | −0.05 |
| $Tl_2SO_4 + 2 e \rightleftharpoons Tl + SO_4^{2-}$ | −0.4360 |
| $U^{3+} + 3 e \rightleftharpoons U$ | −1.798 |
| $U^{4+} + e \rightleftharpoons U^{3+}$ | −0.607 |
| $UO_2^+ + 4 H^+ + e \rightleftharpoons U^{4+} + 2 H_2O$ | 0.612 |
| $UO_2^{2+} + e \rightleftharpoons UO^+_2$ | 0.062 |
| $UO_2^{2+} + 4 H^+ + 2 e \rightleftharpoons U^{4+} + 2 H_2O$ | 0.327 |
| $UO_2^{2+} + 4 H^+ + 6 e \rightleftharpoons U + 2 H_2O$ | −1.444 |
| $V^{2+} + 2 e \rightleftharpoons V$ | −1.175 |
| $V^{3+} + e \rightleftharpoons V^{2+}$ | −0.255 |
| $VO^{2+} + 2 H^+ + e \rightleftharpoons V^{3+} + H_2O$ | 0.337 |
| $VO_2^+ + 2 H^+ + e \rightleftharpoons VO^{2+} + H_2O$ | 0.991 |
| $V(OH)_4^+ + 2 H^+ + e \rightleftharpoons VO^{2+} + 3 H_2O$ | 1.00 |
| $V(OH)_4^+ + 4 H^+ + 5 e \rightleftharpoons V + 4 H_2O$ | −0.254 |
| $W_2O_5 + 2 H^+ + 2 e \rightleftharpoons 2 WO_2 + H_2O$ | −0.031 |

$WO_2 + 4 H^+ + 4$
$WO_3 + 6 H^+ + 6$
$2 WO_3 + 2 H^+ +$
$Y^{3+} + 3 e \rightleftharpoons Y$
$Zn^{2+} + 2 e \rightleftharpoons Zn$
$Zn^{2+} + 2 e \rightleftharpoons Zn($

## REDUCTION

$2 H^+ + 2 e \rightleftharpoons H_2$
$CuI_2^- + e \rightleftharpoons Cu +$
$Ge^{4+} + 2 e \rightleftharpoons Ge^2$
$NO_3^- + H_2O + 2 e$
$Tl_2O_3 + 3 H_2O +$
$SeO_4^{2-} + H_2O + 2$
$UO_2^{2+} + e \rightleftharpoons UO_2^+$
$Pd(OH)_2 + 2 e \rightleftharpoons$
$AgBr + e \rightleftharpoons Ag +$
$S_4O_6^{2-} + 2 e \rightleftharpoons 2 S$
$AgSCN + e \rightleftharpoons Ag$
$N_2 + 2 H_2O + 6 H$
$HgO + H_2O + 2 e$
$Ir_2O_3 + 3 H_2O + 6$
$2 NO + 2 e \rightleftharpoons N_2$
$[Co(NH_3)_6]^{3+} + e$
$Hg_2O + H_2O + 2$
$Ge^{4+} + 4 e \rightleftharpoons Ge$
$Hg_2Br_2 + 2 e \rightleftharpoons 2$
$Pt(OH)_2 + 2 e \rightleftharpoons P$
$S + 2H^+ + 2 e \rightleftharpoons$
$Np^{4+} + e \rightleftharpoons Np^{3+}$
$Ag_4[Fe(CN)_6] + 4$
$IO_3^- + 2 H_2O + 4$
$Mn(OH)_3 + e \rightleftharpoons M$
$2 NO_2^- + 3 H_2O +$
$Sn^{4+} + 2 e \rightleftharpoons Sn^{2}$
$Sb_2O_3 + 6 H^+ +$
$Cu^{2+} + e \rightleftharpoons Cu^+$
$BiOCl + 2 H^+ +$
$Bi(Cl)_4^- + 3 e \rightleftharpoons B$
$Co(OH)_3 + e \rightleftharpoons C$
$SO_4^{2-} + 4 H^+ + 2$
$SbO^+ + 2 H^+ +$
$AgCl + e \rightleftharpoons Ag +$
$As_2O_3 + 6 H^+ +$
Calomel electrode,
$Ge^{2+} + 2 e \rightleftharpoons Ge$
Calomel electrode,
$PbO_2 + H_2O + 2$
$HAsO_2 + 3 H^+ +$
$Ru^{3+} + e \rightleftharpoons Ru^{2+}$
$ReO_2 + 4 H^+ + 4$
$IO_3^- + 3 H_2O + 6$
$Hg_2Cl_2 + 2 e \rightleftharpoons 2$
Calomel electrode,
Calomel electrode,